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Winter Maintenance Study for Reduced Salt Usage

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SUMMARY

An investigation has been conducted into winter maintenance practices in Ontario, with a view to reducing salt usage. The standard salting rate was tested and found to be a good average rate, but should be flexible to fit different weather conditions. A salting rate prediction equation was developed, which should be tested further and expanded. The use of prewetted salt was tested and found to produce hazardous conditions and not result in a saving of salt.

Two different systems for reducing road spray raised by passing vehicles from blowing into adjacent properties were tested and found to be of very limited use. The current use of sand-salt mixtures was investigated to see if this technique would reduce salt usage. In general, it seemed to result in an increased use of salt and greater expended effort.

There exists a wide variance in winter maintenance techniques across the province, which requires greater standardization. Salt usage can be reduced by standardization, close adherence to the guidelines, and by a slight reduction in the level of service.

1/ INTRODUCTION

In 1977, the Ministry of Transportation and Communications (MTC) was asked to determine if it was possible to reduce the amount of sodium chloride (salt) used during the winter months to de-ice Ontario highways. This was requested because of a desire to reduce, as much as possible, any impact which the use of salt might have on the environment [1, 2, 3, 4, 5, 6]. Complaints had been received for several years from orchard growers who suspected that salt spray might be harming their trees and reducing their crops [7]. There was also the fear that salt runoff from the roads during winter might eventually get into the groundwater streams, or aquifers, and contaminate them [8, 9]. In addition, it was known that the salt used on roads during winter accelerated the corrosion of auto bodies [10, 11, 12, 13] and reinforcing steel used in concrete bridge decks [14, 15]. Hence, it was felt that some effort should be made to keep the salt usage down to a minimum, but still give the motoring public the same level of service.

Recommended Ministry Winter Maintenance Procedure

The recommended Ministry procedures for clearing the highways during winter are detailed in Quality Standard M-700-1, and Operating Instructions M-700-C. Each patrol is provided with a sufficient quantity of salt, stored in a salt shed, and sand, containing 5% salt to prevent it from freezing, usually stored in sand domes. The actual clearing procedures used at any time depend on the time of day, the temperature, and other variables. Recommended procedures for various sets of circumstances are listed in M-700-C.

The recommended procedure to clear the remaining snow off a road after plowing, or to de-ice a slippery road, is to use salt spread at 130 kg per two-lane kilometre in a windrow down the centreline of the road. If the temperature is too low, or it is night-time, it is recommended that the road be sanded at a rate of 570 kg per two-lane kilometre to improve traction, then salted when the temperature rises.

A practice has developed in some Districts to add extra salt to the sand

and to use this mixture to remove snow or ice from a road. The quantity of salt used in the mixture has varied, depending on the District and even the patrols within a District. Some claimed that the use of mixtures actually save salt. In line with the desire to keep the use of salt to a minimum, it was decided to review and test our current winter maintenance procedures and to test some new procedures which were reputed to result in a saving of salt.

2/ EXPERIMENTAL

A series of demonstration projects and field observation stations were set up over a five-year period, from the fall of 1977 to the spring of 1982. When these projects were carried out, the stations were manned by young engineers and project supervisors from the Construction Offices of Eastern and Central Regions, since these men were free from their construction duties during the winter months. The projects were designed to test both existing methods and new methods of snow and ice removal from the roads by chemical means. These demonstration projects were as follows:

1/ Compare and evaluate different salt application rates with the standard 130 kg per two-lane kilometre and evaluate a rate prediction equation.

2/ Evaluate prewetting the salt to make it work faster and use a predicted 25% less salt.

3/ Plow and sand only, do not use salt.

4/ Evaluate the use of a chemical incorporated into the asphalt concrete to keep the road surface from icing and the snow from sticking to the road.

5/ Evaluate methods to reduce the spray raised by passing vehicles from blowing onto roadside orchards.

6/ Evaluate different percentages of salt in sand to see if these mixtures might lead to the use of less salt.

3/ DEMONSTRATION PROJECTS

3.1/ Salt Spreading Rates

3.1.1/ Method

In order to determine the effects of different salt spreading rates, two test sites were set up, one near Toronto, and one near London. At each location, a length of highway was signed and set up for the test. Each length of highway was divided into four sections of equal length, and was salted at a rate of 100 kg per two-lane kilometre for the first section; then, at a rate of 130, 155, and 185 kg per two-lane kilometre for each subsequent section.

In order to do this, each of the two patrols was supplied with a salt spreader equipped with variable electronic controls. These controls enabled the operator to change the rate without stopping or leaving the cab.

During the 1977-78 winter, the first section was located in the Owen Sound District on Hwy 50, south of Hwy 89. This was divided into four 2.5 km lengths. The second section was located in the London District on Hwy 3, east of Simcoe. This road was divided into four 2 km sections.

During the 1978-79 winter, the first section was changed from Hwy 50 to Hwy 27. The section was located from the patrol yard for 8 km to the 11th Line in Innisfield Township.

3.1.2/ Observations and Discussion

Over the last two winters, many clearing operations were observed on these two test sections by the investigators. It was noted that in warmer temperatures (around 0°C) 100 kg of salt was sufficient. At other times, in colder temperatures, 180 kg of salt was required to clear the road. The lesser amounts of salt left a lot of packed snow on the road. It did appear, however, that 130 kg was a good average figure for the majority of cases. Figures 1 to 4 show the condition of the second test section on Hwy 3 on January 14, 1978, 3.5 h after salting. This is a typical type of observation.

Figure 1 shows the 100 kg section and here, the melting had stopped and packed snow and ice were forming at the edges. In this case, "bare pavement" was not achieved.

Figure 2 shows the 130 kg section -- the road was starting to dry and was slushy in spots and bare.

Figure 3 shows the 155 kg section -- it was partly wet with no salt residue, and satisfactory.

Figure 4 shows the 185 kg section -- the road is bare and dry and has a salt residue down the centre of the road. This was not satisfactory as salt along the centreline can hold drifting snow and cause it to melt and stick to the road. As more snow drifts in and is held, the brine forming is diluted until its freezing point is reached, then it freezes. A strip of ice forms on the road, and a potentially dangerous situation occurs.

Another situation occurs if conditions require the application of 185 kg of salt, and only the recommended 130 kg is applied. The first application will not clear the road, and a second application of 130 kg has to be applied. Thus, 260 kg are applied, whereas 185 would have done in a single application.

On the basis of these observations, the observers working during the 1977-78 winter developed a salt prediction equation. A survey of the literature [16, 17, 18] shows that various other investigators had recommended rates of 160 to 1620 lb. per two-lane mile per inch of new snow (45 to 457 kg per two-lane kilometre per 25.4 mm of new snow) per °C for 15% to 50% melting.

Reference 4 stated that 15% melting is required to prevent adverse conditions from forming. Under these conditions, the previous rates then vary from 60 to 480 lb. per two-lane mile per inch of new snow per °C. In keeping with the observations in this investigation and Ministry practice, a basic rate of 80 lb./2-lane mile/inch of new snow/°C can be used a guide. The guide equation then becomes:

$$0.9\ A\ B = C \qquad (1)$$

where
A is depth of new snow in mm
B is temperature °C below freezing
C is salt rate in kg/2-lane km

If the snow is hard-packed, then A must be multiplied by 5. Thus, if there is 5 mm of hard-packed snow, the value of A will be 5 x 5 = 25 mm for entry in Equation 1. This equation has been calculated as a nomograph, and this is shown in Figure 5 for easy field calculation.

In use, C, regardless of the prediction, should never be taken as less than 85 and never more than 225 kg/2-lane km.

The use and effectiveness of salt is dependent upon numerous factors. An effort has been made to predict the maximum amount of salt required assuming constant temperature, little wind, light traffic, and no sun. An increase in any of these variables will improve the effect of salt. Therefore, the patrolman should reduce the recommended salt rates, using his experience and weather forecasts. Even at the coldest temperatures at which salt can be used, these quantities should bare the road within eight hours.

It is unfortunate that a concentrated effort could not be made to give this equation a real test over a period of time. Several attempts were made with some degree of success. It was hard to estimate how much packed snow was on the road, since it was usually unevenly distributed. Traffic and radiation from the sky also had their effect. It is recommended that an effort be made in one or two patrols, under a trained observer, to give this equation a real test. Some simple factors on the basis of traffic or radiation could modify it into a useful tool.

3.2/ Prewetted Salt

It was claimed by the distributors of calcium chloride solutions (32% by wt. $CaCl_2$) that, if the salt was prewetted with this solution, it would work faster to melt ice and snow and the amount of salt could be reduced by 25%. The recommended dosage was to spray the load of salt with the solution at a rate of 40 L per tonne of salt and let it percolate through the load.

In order to test out this product, two locations were chosen, one in London District, and one in Port Hope District. At each test area, three sections of road were selected. One section was treated with salt prewetted with the calcium chloride solution (Caltreat), at a rate of 100 kg/2-lane km; this was an approximate reduction of 25% from the standard 130 kg. An adjacent section was treated with regular salt at the standard rate of 130 kg/2-lane km, and a third section was treated with regular salt only, at 100 kg/2-lane km, in order to get a complete comparison.

In the London District, the Courtland patrol was to apply salt with Caltreat along Hwy 3 between the Town of Delhi and the Tillsonburg bypass. There were two areas of interest along this stretch of highway. The Tillsonburg bypass to the Hwy 59 South intersection portion is subject to heavy morning and afternoon rush hour traffic volumes. The Hwy 59 South intersection to Delhi section does not experience the heavier traffic volumes and, hence, might have caused the Caltreat-covered salt to react differently. The control section of highway was maintained by the Tillsonburg patrol. This section was Hwy 3 from the Tillsonburg bypass to the west. The standard 130 kg/2-lane km of salt was applied. In addition to the 130 kg/2-lane km control, another section of Hwy 3 to the east of Delhi was treated with 100 kg/2-lane km of untreated salt. This highway was maintained by the Norwich patrol and was intended to provide a comparison between 100 kg/2-lane km with and without Caltreat. The Norwich patrol also maintained Hwy 59 North at 130 kg/2-lane km. This highway offered a good comparison between a north-south aligned highway and the east-west aligned Hwy 3.

The second test site was located in the Port Hope District. The Norwood patrol applied salt with Caltreat at 100 kg/2-lane km along Hwy 7 east of Norwood. The Norwood patrol also applied the standard application on Hwy 7 west of Norwood. The Roseneath patrol applied straight salt at 100 kg/ 2-lane km on Hwy 45 south of Norwood for additional comparisons.

The Caltreat was applied at both patrols via an overhead spray bar located at the patrol yard. The apparatus consists of a 5000 gallon tank to store the Caltreat, a pump to propel the liquid from the tank through the spray bar, and a spray head consisting of 18 nozzles to create a

fan-shaped spray. The spray bar was pivoted on a pin to allow the sander operator to raise the apparatus and permit him to position his truck under the spray head. The head was then lowered to within one foot of the top of the sander and the pump was activated.

The pump was controlled by a timer after a manual start switch had been depressed by the sander operator. The length of time that the pump was in operation was determined through a simple calibration technique.

3.2.1/ Observations and Discussion

The two test areas were not ready for operation until late in the 1977-78 winter. As a result, the first few trials were run at temperatures close to 0°C. In these first trials, the Caltreated salt did clear the road, and it appeared that prewetting the salt showed some promise. The following winter, 1978-79, presented a different picture. During the cold weather, some severe refreezing occurred and hazardous situations developed.

The Ministry's standard practice is to spread the salt in a windrow, about 0.5 m wide down the centreline of the road. Here, the salt slowly begins to work and form a brine which traffic works across the road. The packed snow is thus loosened and traffic works it off the road. When the prewetted salt was used, it went to work very fast and formed a brine quickly in the centre of the road. Snow blowing into this brine diluted it and it froze, leaving a sheet of ice down the centre of the road. When salt is used, the snow is worked off the road by traffic, and the road dries. With calcium chloride, the road never dries because the salt is deliquescent, thus blowing snow sticks to the road and the road has to be resalted.

Following are summaries of the records made by the observers at the Courtland and Norwood patrols.

Summary of Observations at Courtland

A total of six applications were reported at Courtland. The temperature range for the observations was from -7° to 0°C. In most instances, the areas treated with Caltreat became slippery and had to be treated with

either sand, or sand plus salt. On January 7, 1979, Caltreat was used. It had been snowing, with a temperature of -6°C. The winds were light and blowing across the highway, with snow-covered road conditions prior to applying the Caltreat. The salt, at 100 kg/2-lane km, plus Caltreat combination, was applied at 10:00 A.M. According to the patrolman, this had little effect on the snow.

Another application of salt plus Caltreat was made at 12:00 Noon. The snow began melting very slowly. After some time the road was slushy with many icy areas. Later in the afternoon, straight salt at 130 kg/2-lane km was used to melt icy spots.

The control section, that section of road where straight salt at 130 kg/2-lane km was used, became bare with wet sections within 2 h after application. This same situation occurred numerous times.

It appears that, at times, the Caltreat works well when initially applied. The problem occurs once the snow has begun to melt. It seems that with the addition of Caltreat, the combination of snow and brine tends to slowly freeze. The patrolman noted that, at colder temperatures, the pavement treated with Caltreat would usually freeze over. This would necessitate either sanding or placing a sand plus salt mixture in order to clear the icy sections. The other problem noted at Courtland was that when any snow would build up over an application of Caltreat, a brine layer would then form on the road surface. A further application of Caltreat would have little or no effect on this layer, while an application of straight salt would normally clear the road. In nearly all situations when Caltreat was used, sand and salt had to be applied in order to clear the road, while the section of road where straight salt had been used did not require further sanding or salting.

Summary of Observations at Norwood

The use of Caltreat at the Norwood patrol yard experienced problems similar to those at the Courtland patrol. A member of the test team was able to observe 3 or 4 applications of Caltreat at the Norwood test site. On January 8, 1979, the application rate of Caltreat at Norwood was changed from 40 L per tonne of salt down to 30 L. This change resulted

from complaints by the patrolman and the truck operator that the Caltreat was percolating through the load of salt prior to the salt being placed on the road. Of particular interest, are the applications of Caltreat on January 24, 25, 26, and 27.

On January 24, 1979, the Norwood area received 15.4 mm of rain and 10.6 mm of snow. The temperature for the 24th ranged from -5° to -9.5°C. On January 25, the patrolman decided to use salt and salt plus Caltreat. The initial application began at 10:00 A.M. At this time, the temperature was +1°C. The road was snow-packed with 15 mm to 20 mm of snow, with some slushy areas. The temperature remained at or near zero during the entire day. As a comparison, temperatures at Peterborough were -1°C at 10:00 A.M., 0°C at Noon, and remained at 0°C until 6:00 A.M., January 26.

The salt plus Caltreat was applied from the Asphodel 7th Line, east to the Town of Marmora, while straight salt at 130 kg/2-lane km was applied from the Asphodel 7th Line, west to Peterborough. The Caltreat worked fairly well for the first 1 to 2 hours. A common occurrence with the use of the salt plus Caltreat was that there was pronounced spotting. The salt plus Caltreat seemed to be working for 2 to 3 m, then not working for a few metres, etc. Within the first two hours of applying the salt plus Caltreat, the road was in a track-bare condition. The road where straight salt at 130 kg/2-lane km was used was in a bare, although wet condition. Within 3.5 h after the Caltreat had been applied, the road was centre-bare with many icy and slushy areas between the wheeltracks.

It began to snow at 2:00 P.M., and continued to snow until 3:00 P.M. The road conditions were changing from track-bare with icy sections to ice-covered with small areas of track-bare and centre-bare pavement. The driving conditions were very poor, with road conditions varying from track-bare, but wet, to completely ice-covered. At the same time, the section of road where straight salt at 130 kg/2-lane km had been used, was in a bare but wet condition. It was observed that the section of road where straight salt had been used was able to continually melt any new snow that was falling on it, as well as preventing the brine from freezing.

At 2:30 P.M., the patrolman decided that the road was in a dangerous condition, and ordered a mix of sand plus salt to be placed on the east section of our test area (that area where Caltreat plus salt had been used). The patrolman decided to include sand with the salt so that it could provide traction on the ice. At 5:00 P.M. another application of the sand and salt mix had to be placed over this same section in order to remove the ice accumulation. It should be mentioned that according to the Scientific Services Section of Environment Canada, who operate a weather data gathering station at Norwood, the total snow accumulation at Norwood for the 25 of January was less than 10 mm. The important factors to consider are that salt at 130 kg/2-lane km cleared the road faster than did the salt plus Caltreat, melted any new snow that fell on the roadway, and did not allow the brine to freeze. The salt plus Caltreat did not do any of these, but the most important factor is that the new snow that fell (10 mm) could not be melted by the salt plus Caltreat.

On January 29 and 30, this same area received a minor storm. Total snow accumulation for the 29th was 40 mm of snow, while an additional 20 mm fell on the 30th. It had begun snowing at 9:30 P.M. on the 29th, and continued to snow until the next morning. The salt and the salt plus Caltreat were applied about one-half an hour after it had begun to snow. The temperature at this time (11:00 P.M.) was -6°C. One and one-half hours after applying the salt plus Caltreat, Hwy 7 from the Asphodel 7th Line through the Town of Norwood was in a wet and slushy condition. The area from Norwood to Marmora was completely snow-covered (this was the area treated with Caltreat). The road conditions on the area where Caltreat had been used did not change during the night. The control section, that section where salt at 130 kg/2-lane km was used, was mostly bare with some snow-covered sections. At 10:00 A.M. of the next morning, the 30th, the east section of road (treated with Caltreat) had to be re-salted with 180 kg/2-lane km in order to clear the snow.

The observations made on these particular days were the same as on at least 10 to 15 separate occasions at the Norwood Test Site. The results indicate the following.

- Salt at 100 kg/2-lane km plus Caltreat at 30 L per tonne of salt did not melt and clear any accumulated snow.

- The addition of 40 L of Caltreat per tonne of salt proved to be excessive, i.e., the Caltreat began leaking through the load of salt.

- The brine (melted snow plus Caltreat plus salt) would often freeze over. In many cases, this required additional salting, sanding, and plowing.

Once it was decided that 100 kg of salt plus 40 L of Caltreat per tonne of salt was not working properly, changes were made to vary the application rate to 130 kg of salt with 30 L of Caltreat per tonne of salt. This change was made during the first week of February, and only two observations at this application rate could be made. The first was on February 8, and the second on March 1, 1979. On February 8, the road conditions at the time of application were snow-covered with some icy sections. The temperature was -4°C and rising. The weather was sunny with some light, dry snow. The initial application was made at 11:00 A.M. The section from Norwood to Peterborough was treated with 130 kg of salt per 2-lane km, while the section from Norwood to Marmora was treated with a mixture of salt at 130 kg/2-lane km plus 30 L of Caltreat per tonne of salt. The section of road treated with salt at 130 kg without Caltreat was bared fairly quickly and remained bare even though it continued to snow. The section treated with salt plus Caltreat remained snow-covered except for a 2-foot strip where it was slushy. The section treated with Caltreat had to have a second application, plus continuous plowing in order to keep the road in a bare condition.

The second observation was made on March 1, 1979. The weather was wet snow mixed with sleet and freezing rain with a temperature of -2°C and rising. Winds were light and blowing across the highway. The road was in a snow-covered condition. Salt at 130 kg plus Caltreat were placed on the east end of the test section at 10:10 P.M., and at 12:00 A.M., while salt at 130 kg was placed on the west section. The section treated twice with Caltreat covered over fairly quickly in light snow, while the section with straight salt remained relatively bare with only one application.

These results showed that prewetted salt, when windrowed down the centreline of the road, was not as efficient as regular salt. Rather

than save 25% of salt usage, it caused more salt to be used to remove the ice and packed snow and created, at times, a hazardous situation.

3.3/ Plow and Sand Only, Do Not Salt

It had been suggested that the roads could be maintained in winter by plowing and sanding only. This would permit a snow-packed and ice condition to build up on the road, at times, throughout the winter. Sand, with 5% salt added to keep it from freezing, would be used to improve traction on the road. This, of course, would require users of the road to travel at a reduced rate of speed in order to prevent accidents.

A section of Hwy 24, south of Simcoe, was chosen for the test. The patrolman was instructed to plow and sand only. He was, however, given the option to use salt to clear the road should, in his opinion, a dangerous situation exist. This latter option really prevented a thorough test from being carried out. People using this section of road were used to bare pavements in other sections. Therefore, they could not be suddenly subjected to a rough, somewhat slippery pavement without warning. It was felt that the patrol was legally responsible to keep the road in reasonably good repair.

As an example of this, one day there was a fall of wet snow. This was plowed from the road. There were always some patches of snow left on the road after plowing. Some of this melted, and the next day the temperature dropped and ice formed on the road. Rather than sand this, the patrolman decided it was dangerous and removed it with salt.

As snow packs build up on the road, they tend to pot-hole with the odd thaw, and become rough and dangerous. Again, a massive dose of salt was necessary to clear the road. This demonstration project was discontinued, since nothing could come from it unless an entire large area was designated and the public was fully aware of the project.

3.4/ Built-in De-icing Compound

There is a European-developed additive available for asphalt road

surfacings which is claimed to prevent surface icing and snow from sticking to the road surfaces. The compound is known as Verglimit, and it is essentially calcium chloride flake (80% $CaCl_2$ and 20% H_2O) with 5% caustic added and the particles coated with polymerized linseed oil to waterproof them. This material is blended in with the asphaltic concrete surfacing mix at 5% by wt. and the mix laid on the road in the normal manner. Traffic wears the road surface and bares the Verglimit particles. These particles absorb moisture from the air and form small pockets of brine. This brine prevents bridge deck icing in late fall or early spring by preventing ice from sticking to the deck.

In October, 1977, a bridge deck on Hwy 9 and a 300 m length of pavement on Hwy 48 were paved with a surfacing containing Verglimit. These were observed to see if such a surfacing might reduce the amount of salt required to keep the pavement bare and prevent skidding accidents on icy bridge decks. Observations were carried out by the observation teams during the 1977-78 and 1978-79 winters.

3.4.1/ Observations and Discussion

In 1977-78, the early storms in December were very cold and windy. Temperatures ranged from -5° to -8°C and the winds caused the snow to drift across the bridge deck and Hwy 48. The Verglimit did not have an opportunity to work on the snow, as it blew across the road. On December 8, however, some melting action was noted at the edge of the pavement on Hwy 48. The Verglimit pavement was slush-covered, while the standard HL-3 asphalt was snow-covered. On January 10, 1978, there was a light snowfall at a temperature of -18°C. The snow did not adhere to the deck and the traffic cleared the deck. The road on either side of the bridge was snow-covered, due to the traffic packing the snow, and it adhered to the road surface.

Discussions with the patrolmen during the 1977-78 and 1978-79 winters elicited the information that the bridge on Hwy 9 tended to ice up less than a similar bridge, and that this bridge and the Verglimit patch on Hwy 48 were easier to plow than the other areas.

It would appear that the Verglimit did, to some extent, prevent bridge deck icing. A survey of accident records showed that there had been four

skidding accidents in winter on the icy deck, from 1973 to 1976. From 1977 onward, after the Verglimit surfacing was applied, there had been no accidents on icy pavements. This compound then, when incorporated into the asphalt surfacing, should reduce salting of the deck, which is done to prevent icing.

3.5/ Road Spray Reduction

There had been complaints from orchard owners along some highways, who alleged that salt spray from the highway was causing damage to their fruit trees. The spray was caused by vehicles on the highway and blown by the wind onto the trees. It was hypothesized that if ruts in the road surface and ruts in the gravel shoulder at the pavement edge could be avoided, then brine would not collect there, and the spray would be reduced. Such a reduction could be effected by increased maintenance and by paved shoulders. In order to test this hypothesis out, a series of locations was chosen in each of the winters (1977-78 and 1978-79), where there were rutted gravel depressions at the pavement and where there were paved shoulders. In order to simulate the latter, areas were chosen where there were paved "Off" ramps.

Rubber buckets were placed in the orchards, or fields, at 18, 24, and 30 m from the edge of the pavement to collect the spray. Since the number of salting or sanding trucks would not be the same past all stations, it was necessary to work out a factor to reduce the amounts of chloride collected at each station to a common basis. The basis chosen was the average amount of chloride laid down on one square metre per standard salting pass, spreading salt at a rate of 130 kg/2-lane km. At each station, the number of salting and sanding passes were taken from the patrol records. The sand, which was spread, contained 15% salt. This was equivalent to spreading salt at a rate of 85 kg/2-lane km. These were converted to an equivalent amount of standard salting passes. The total number of standard salting passes at each station were then divided into the total amount of chloride collected and the results calculated to the common basis.

During the 1977-78 winter, four sections were chosen. These were:

- Section A -- Paved Shoulder -- N side of QEW
- Section B -- Gravel Shoulder -- S side of QEW
- Section C -- Gravel Shoulder -- N side of QEW
- Section D -- Paved Shoulder -- S side of QEW

The buckets were changed every 14 days and brought into the laboratory for chloride analysis. This was continued for eight weeks.

During the 1978-79 winter, eight sections were chosen. They were as follows:

- Section A -- Paved Shoulder -- S side of QEW
- Section B -- Gravel Shoulder -- S side of QEW
- Section C -- Gravel Shoulder -- S side of QEW
- Section D -- Paved Shoulder -- N side of QEW
- Section E -- Gravel Shoulder -- S side of QEW
- Section F -- Gravel Shoulder -- N side of QEW
- Section G -- Gravel Shoulder -- N side of QEW
- Section H -- Paved Shoulder -- N side of QEW

The buckets were placed in orchards or fields as in the previous winter. This time, however, they were changed every two to four weeks as weather permitted. Again, this test lasted about two months, and three changes of buckets were made.

The results obtained for the two winters are shown in Tables 1 and 2, where the amounts of chloride per square metre standard salting pass are recorded.

During the 1979-80 and 1980-81 winters, another series of tests was run. An idea was advanced that, if 50% open-slat snow fencing would spill snow from a windstream, it might perhaps prevent some spray from being blown into the orchards. In order to test this idea, four test sections were set out in 1978-79, and seven sections in 1979-80.

In the winter of 1978-79, four test sections were set out in January, 1979. At the four orchards selected, 152 m (500 ft.) of 1.2 m (4 ft.) snow fence were installed, three on chain link security fence, and one on

farm fence. Two were on the north side of the QEW, and two on the south side. The snow fence was attached to the security or farm fence with wires and with the level of the snow fence even with the top of the security or farm fence at crown height (2 m). This testing was done in co-operation with the Air Resources Branch of the Ministry of the Environment (MOE).

In order to measure the effectiveness of this barrier, moss bags to collect the spray were placed at spaced intervals in the orchard by MOE, and attached to the trees. These bags were of open nylon mesh and were filled with sphagnum moss. This technique was developed by MOE, and proven effective. The bags were changed at fixed intervals. One set of bags was placed behind each row of snow fencing, and a set of bags was placed outside one end of the snow fencing. Analysis of the chloride content of each set of bags would then show if the snow fencing reduced the amount of salt spray going into the orchard. During 1978-79, two changes of bags were made -- January 23 to February 21, and February 21 to March 23.

During the 1979-80 winter, three more test sections were added and these, together with the four from the previous winter, were operated to further test the effectiveness of the fences. This time, five one-month periods were analysed, December to May.

During the 1978-79 winter, two metal poles with moss bags attached were erected (one north, and one south of the QEW) to determine how high the salt spray was thrown by passing vehicles. These poles were 9 m high and were placed 38 m from the pavement edge of the QEW. Moss bags were attached to the poles at 1, 2, 3, 5, 7, and 9 m above ground level. These bags were removed at one-month intervals and tested for chloride content.

A further test was run during 1978-79 to determine how far back in the orchards the salt spray travelled. For this test, moss bags were mounted on fruit trees at crown height (2 m) and spaced at 38 m from the road to 410 m. Two sets of one-month exposure were run in this test.

All of the moss bags and their mounts were provided by, mounted by, and

analysed by MOE personnel.

3.5.1/ Observations and Discussion

3.5.1.1/ Paved vs. Gravel Shoulders

The results shown in both Tables 1 and 2 illustrate that there was less spray, on the average, in the orchards where paved shoulders were present. In Table 1, for the 1977-78 winter, the reduction in spray for paved shoulders was about 32% while, in 1978-79, the reduction was about 17%.

When the test sections were grouped according to the side of the highway, north and south, it was found that, in 1977-78, most winds were from the south-east and the north side had the heaviest spray, while the reverse was true for 1978-79.

The numbers shown in Tables 1 and 2 may appear large. It must be remembered, however, that these figures are milligrams per square metre. The standard salting rate spread salt at 130 kg/2-lane km (65 kg/lane-km or 65000 mg/lane-metre). Of this 65000 mg, only a small portion is blow onto a square metre of orchard.

The use of paved shoulders would thus reduce somewhat the amount of spray blown into the orchard from the road.

3.5.1.2/ Snow Fencing as a Spray Barrier

The results of two years' observations showed very little reduction in spray where snow fencing was placed on either the security fence or on farm fence. When a statistical analysis was done on the data, any difference between the fenced and unfenced areas had to be rejected. If any difference did exist, it would be so small as to be of no use to the orchard grower.

A complete listing of all these data, their analysis, and a description of the moss bags, is given in the following reference:

McLaughlin, O. L. and Pearson, R. G., "Effectiveness of Snow Fence Barriers in Reducing Salt Spray Injury to Fruit Orchards Adjacent to the Queen Elizabeth Highway, 1978-1981," Ontario Ministry of the Environment,

Phytotoxicology Section, Toronto, January, 1982.

3.5.1.3/ Spray Penetration into Orchards

The depth of spray penetration into the orchards is shown in Table 3. The moss bags were placed in six rows of trees from 38 m to 410 m. It can be seen that the spray penetrated to 410 m and varied with the winter months.

The analysis of the chloride content of the moss bags placed on poles to determine the height of the spray pattern showed that the spray travelled to heights in excess of 9 m. Figure 7 is a graph showing the spray density against height at a point 38 m from the highway. These two figures, 6 and 7, show how high and far the spray raised by passing vehicles can travel into surrounding properties.

It would seem that the only way to contain or reduce the spray is to partially enclose the vehicle wheel recesses, attach large flaps behind the wheels, reduce speed limits, or enclose the highway with solid fences similar to noise barriers. All of these possible remedies carry drawbacks and cause further problems. Enclosing the wheel recess could lead to over-heated brakes, reduced speed limits would be difficult to enforce, and solid barriers could lead to snow drifting and snow clearance problems. Spray can, however, be reduced by good maintenance of the road to remove ruts, and paved shoulders to prevent ponding of the salt brines during winter.

3.6/ Sand-Salt Mixtures

There are many different opinions in the Districts on how to best de-ice or remove packed snow from a road. The Guidelines in M-700-C recommend the use of salt for this purpose. The use of sand, with 5% salt in it to keep it from freezing, is recommended to skidproof a road to provide traction.

The use of sand-salt mixtures with more than 5% salt added has grown in several Districts, where they are used to both skidproof and de-ice a road. Mixtures from 15% to 50% salt are being used. In some Districts, the sand piles are put up with 15% salt, rather than the recommended 5%

salt. One District uses mixtures almost exclusively, with only an occasional use of straight salt, while another District uses very little sand and relies mostly on straight salt. The other Districts fall somewhat in between.

The various mixtures used are blended in the patrol yard by the use of a front-end loader. One method of blending is to take a loader bucket of salt and spill it on the sandpile. Then, if two buckets are removed from that area of the pile, it is a 1:1 mix, or 50% salt. If four buckets are removed, it is a 1:3 mix or 25% salt. This does not take into account the amount of salt already in the sandpile. Another method of blending is to lay out the salt and sand in a windrow and blade it, then store it in a "hot pile".

Those who use the mixtures (15% salt and greater) claim that they are more efficient and can save money. One claim for the 15% salt mixture is that when it is spread on the road at night when it is too cold for salt alone to act, the heat generated by the traffic causes the salt to act and the sand keeps the salt on the road. Another claim is that when 15% salt mixture is spread at 570 kg/2-lane km, the amount of salt used is 85 kg. It is claimed that this does the same job as salt alone spread at 130 kg/2-lane km. If this is true, then there is a salt saving, but more operator and truck time are involved and these are expensive. The same claim has been made by those who spread the higher percentage salt mixtures. They claim they use less salt and save money. This may be true, but a lot more sand and operator-truck time are involved. The reverse claims are made by those who rely largely on 100% salt with a lesser use of sand. In order to try to resolve these differences and see if the use of mixtures could result in a saving of salt, a large demonstration project was designed and put in operation during the 1981-82 winter.

3.6.1/ Project Design

It was decided that nine observers (construction project supervisors) would be selected and each stationed in one patrol yard to observe the operations and the effect on a given stretch of highway.

A record form was designed so that the weather conditions, operations,

and results could be checked off. These cards were designed so that the data could be keypunched and recorded on one computer card. There was space on the fourth side of the form for any comments the observer might care to make. This form is shown in Figures 8a, 8b, and 8c.

All observers were carefully instructed in what to look for, so that the results could be compared. The recording form itself was designed in consultation with the Maintenance Engineers, Maintenance Supervisors, and the patrolmen, so that all pertinent data would be included. The observers were told that they must not influence the patrolman or night patrolman in any way as to the treatment to be given to the road. They were there simply to record weather and road conditions, what was done, the results obtained, and the time required to obtain the results.

In order to compare the two extreme maintenance practices (mixtures vs. straight salt), pairs of patrols were selected on the same highway, either adjoining or reasonably close together. Both multi-lane and two-lane highways were selected. The pairs were as follows:

- Hwy 401 -- Multi-lane, Divided, E-W Direction

  Section A -- Mainly salt, some sand with 5% salt.
  Section B -- Mainly mixtures, some pure salt.

- Hwy 15 -- Two-Lane, N-S Direction

  Section D -- Mainly salt, some sand with 5% salt.
  Section E -- Mainly mixtures, 15% to 50% salt.

- Hwy 7 -- Two-Lane, E-W Direction

  Section F -- Mainly mixtures, 15% to 50% salt.
  Section G -- Mainly salt, some 5% and 15% salt in the sand.

In addition to the comparison of these two different methods of clearing the road, it was necessary to compare results obtained in patrols where 5% salt in sand was stockpiled with those obtained where 15% salt in the sand was stockpiled. In order to do this, two more patrols were

selected:

- Hwy 6 -- N-S Direction

  Section C -- Multi-lane, salt and sand with 15% salt.
  Section H -- Two-Lane, salt and sand with 5% salt.

- Hwy 20 -- E-W Direction

  Section J -- Two-Lane, J_1 -- Salt and sand with 15% salt.
  J_2 -- Salt and sand with 5% salt.

Each patrol was provided with two stockpiles of sand, one with each salt concentration. One section of each patrol would be treated with either salt or sand with 5% salt, and another section would be treated with salt or sand with 15% salt. Section G was also provided with the two types of sand, so that it could enter both comparisons.

The observers began observing the operations near the beginning of December, 1981, and continued through to the end of March, 1982.

It was planned to run multiple regression analyses on the data using the "Time to Clear" as the dependent variable, and all of the other factors as independent variables. In this way, the salt concentration, spreading rate, weather condition, etc., should show what effect they have on the clearing rate and possibly indicate the most efficient way to clear the road.

3.6.2/ Test Results

As soon as the completed forms began arriving for processing, serious difficulties were obvious. Even in a mild storm, there would be several passes of the salt or sand spreading trucks, and a form was received for each pass. Until the final pass, no clearing time could be recorded, and this was the time from when the last truck went down the road and the road was declared satisfactory. The previous trucks could not be included, since there were plowing passes in between the salting or sanding trucks, which would remove the material from the road. Another

factor was the very different thinking on how to clear the road. It varied from one patrolman to another. In one icing storm, one patrol was spreading only salt, while the adjacent patrol was spreading a sand mixture. On another occasion, it was obvious that the night patrolman was operating differently from the day patrolman.

In mid-January, regression analyses were run for each section. About the only independent variable found significant was "Temperature," when all of the data were pooled and analysed. Together, the correlation was even less.

At the end of the winter, the multiple regression analysis was run on all of the cards on which a "Road Clear" time was recorded. The data were divided into two groups -- Multi-lane Roads and Two-Lane Roads. It was first run on the individual sections, and then on the sections of each group combined.

The regression equation was of the form:

$$Y = 1 + A\,x_1 + B\,x_2 + C\,x_3 + D\,x_4 + E\,x_5 + F\,x_6 + G\,x_7 + H\,x_8$$

where: Y = clearing time in minutes
I = intercept
A, B.... H = coefficients of the variables
x_1..... x_8 = variables defined in Figures 8(b) and 8(c)

The results are shown in Tables 4 and 5. In these tables, the first column lists the section, the second, the number of tests. The third column gives the F value. This is the ratio of the mean square of the model over the mean square for error. The fourth column is a significance test, and low values (less than 0.05) indicate significance. The fifth column is the R^2 value and represents the amount of dependence of the dependent variable on the listed independent variables. Column 6 is the coefficient of variation, and Column 7 is the standard deviation.

Column 8 lists the mean of the dependent variable, "Road Clear" time in minutes. The remaining columns list the values for the intercept and the

coefficients of the variables used. Some squares in Tables 4 and 5 are shaded. These are variables which, in that section, were significant at a 95% confidence level. Where the letter "B" is shown beside a value, indicates the computer considered there was a bias present.

An examination of all the data in Tables 4 and 5 shows the following:

a/ Generally, the correlation between Clearing Time and the independent variables is poor, as shown by the low R^2 values and the few coefficients which showed up as significant.

b/ It is surprising that the % Salt (Column 15) never did become significant, especially in Sections B, E, and F, where there was heavy use of mixtures.

c/ The best correlation was found in Section C, where the F value was high, the $R^2 = 0.863$, and four independent variables were significant. This suggests the patrolman here was guided by weather conditions, radiation from the sky (X_1), sun (X_3), and temperature (X_8), in his decisions.

d/ When data from all three multi-lane roads were combined (last line of Table 4), all correlation vanished. The R^2 value was 0.1168. This can only mean that every patrolman had his own set of standards and worked in a different manner. Yet, all kept their roads clear, some faster than others. This latter is shown by the values in Column 8, Mean Road Clearing Time.

e/ Examining the data from the two-lane roads, Table 5, shows that Section F had an R^2 value of 0.526 and five significant independent variables. This indicates that this patrolman was influenced by weather conditions to a greater extent than the others. Sections D, H, and J also showed high R^2 values, but very few significant independent variables. This does not mean that they were not significant at the 95% confidence level.

f/ Again, in Table 5, all sections combined had the lowest R^2 value, which again means that all (or most) of the patrolmen think and

operate differently.

In an attempt to get better correlation between the variables, another grouping was tried. The three sections in the District emphasizing mixtures, (Section B, E, and F) were combined in one analysis and the 100% salt emphasizing sections (Sections A and D) were combined in another group. The results were as before on the grouping, with very low R^2 values. These results are not reproduced in this report, since they were of no value.

The regression analyses did not enable any choice to be made between the use of mixtures and 100% salt or between 15% and 5% salted sand. As a result, the data were grouped in another way to compare the effectiveness of these different methods.

The data were organized in section pairs where the data were analysed in another way. There, the data were compared in section pairs where similar situations prevailed, but different techniques were used. In order to do this, only storms or situations were counted where the observer in each of the sections was on duty. Due to overtime, vacations, etc., the observers were not always on duty at the same times; hence, some storms or icing situations had to be dropped.

The pairs of sections to be compared were:

- Hwy 401 -- Multi-lane, Sections A and B
- Hwy 15 -- Two-Lane, Sections D and E
- Hwy 7 -- Two-Lane, Sections F and G

These pairs compared the mainly mixture technique against the mainly salt technique.

The comparison of the sand containing 15% salt against the use of sand with 5% salt was more difficult. The 15% material was being used as both a de-icant and abrasive, while the 5% material was being used only as an abrasive.

The comparison of these two sand mixes will be shown and discussed later

in this report.

The comparison of operations in the two Sections A and B on the multi-lane highway is shown in Table 6. Here, it can be seen that in Section B, both mixtures and straight salt were used while in Section A only straight salt was used. These are two adjoining sections on Hwy 401 and are subject to similar weather conditions. It must be emphasized that these were not the only de-icing operations performed on these two sections. These are only the operations which occurred when both observers were on duty at the same time. The results are summarized in the first two lines of Table 12.

Here, it can be seen in line two of Table 12, that Section B required fewer treatments and salt to keep it open than did Section A, where straight salt was used. The greater amount of traffic in Section B could help account for this. However, there was a great difference in average clearing time -- Section A was cleared more than three times faster than Section B. Both sections used, on the average, the same amount of salt per treatment (Column 6 of Table 12). It would thus appear that there is an indication that salt alone works faster than do mixtures, and there is an urge to clear the road faster in the District to which Section A belongs than in the District where Section B belongs. This same indication will be apparent in the following pairs.

The comparison of operations in the two adjoining Sections D and E on a two-lane highway are shown in Table 7. As before, the sections were adjoining but the traffic was the same on both sections. Section D, during the observed operations, used only straight salt, no sand was used, while Section E used all types of mixtures and straight salt. The summary of these operations is shown in Table 12. Here, it is shown that fewer passes were necessary to clear the road in Section D with straight salt, than in Section E. The total amount of salt used on the observed operations was similar in both sections; this is shown in Column 5 of Table 12. As a result, the amount of salt used per treatment was higher in Section D. The clearing time for the road was less in Section D where straight salt was used, than in Section E where mixtures were used. This follows the pattern shown in Sections A and B.

The third pair of Sections, F and G, were located on a two-lane highway,

but farther to the west than Sections D an E, and they were not adjacent. They were separate by 100 km (60 mi.). Each one of these sections was divided into two parts, one to the east of the patrol yard, and one to the west. The purpose of the division in Section F was simply to get two sets of readings for mixtures in conjunction with Sections A, B, D, and E. The purpose of the division in Section G was to study 15% salted sand against 5% salted sand. The District in which Section G was situated was a District where the guidelines given in M-700-C were followed. In this District, the sand was used to skidproof a road and not for de-icing purposes, as in the District where Sections A and D were situated. As a result, for comparison with Section F, both halves of Section G were combined and compared to both halves of Section F. The results are shown in Table 8. There was almost twice as much traffic in Section G as in Section F, and this made it somewhat difficult to compare the results. More treatments were used in Section G than in Section F, but much more salt was used in F than in G. The results are summarized in Table 12. Here, it is shown that the average amount of salt per treatment (Column 6) was much higher in Section F than in G, but the clearing time was faster in G than in F. No doubt, the heavier traffic in Section G helped here, but the use of mixtures in Section F did appear to require the use of more salt.

These three pairs of sections have shown that salt alone can clear a road and, most probably, clear it faster than can mixtures of salt and sand. The District which stressed mixtures, and in which Sections B, E and F were located, took longer to clear the roads than did the District in which Sections A, D, and G were located and which stressed salt for de-icing purposes. Another factor which must be considered where mixtures are concerned is that more time is required to get them on the road. One five tonne truckload of salt will cover approximately 40 km of two-lane road, spreading salt at 126 kg/km. It will require 2.7 loads of sand mixture spread at 340 kg/km (1200 lbs./mi.) to cover the same distance, and it will require 4.4 loads of mixture spread at 560 kg/km (2000 lbs./mi.) to cover the same distance. Thus, much more effort is required to spread mixtures than is required to spread straight salt on the road, and more time and manpower could be the result.

The sections chosen to compare 5% vs. 15% salt in the sand were as

follows:

- Hwy 7 -- Two-Lane, E-W

  Section G_1 -- 5% salt in sand and 100% salt.
  Section G_2 -- 15% salt in sand and 100% salt.

- Hwy 6 -- Multi-lane and Two-Lane, N-S

  Section C -- 15% salt in sand and 100% salt.
  Section H -- 5% salt in sand and 100% salt.

- Hwy 20 -- Two-Lane, E-W

  Section J_1 -- 5% salt in sand and 100% salt.
  Section J_2 -- 15% salt in sand and 100% salt.

One observer was assigned to each of the above three pairs of sections.

The results obtained in Sections G_1 and G_2 are shown in Table 9. Here, each section received almost identical treatment, except 5% salted sand was used on Section G_1 and 15% material on Section G_2. On three occasions, for convenience only, some 15% material was used on Section G_1. The snow clearance technique practised at this patrol was to use the sand to skidproof the road only, and not for de-icing purposes -- hence, on most dates shown in Table 9, the same types of treatment were used. Only on December 21 and January 6 were conditions on the two sections different, and different treatments were required. The average time to clear the road was the same for both sections, as shown in Table 12. The total amount of salt used was higher in Section G_2 where the 15% material was used. Under the conditions and methods used in this section, there was no apparent advantage to either the 5% and 15% salted sand. Here, the 15% material simply put more salt into the environment.

In Sections C and H, the situation was not as clear as in the G sections. In Section H, where the 5% salted sand was supposed to be used, a problem arose at the end of January. The 5% material ran out and 15% material had to be used to the end of winter. This somewhat clouded the issue.

In addition, the traffic on Section C was double that on Section H. The results from this section are shown in Table 10. Here, it can be seen that more total salt was required to clear four lanes of Section C than to clear the two lanes of Section H. The mean clearing times for Sections C and H are shown in Table 12, and they are 47 min and 36 min, respectively. From this, it is clear that the patrol was able to clear Section H with the 5% material as long as it was available and used less salt in the process.

The results obtained on Sections J_1 and J_2 are shown in Table 11 and, here, another difference is apparent. There were 20% fewer passes made with the spreader in the 15% salted sand section than in the 5% section. It is obvious, here, from the number of sanding passes made along with the salting passes that the patrol was trying to de-ice the roads at times with the mixture rather than with salt alone. The clearing time on both sections was good, 74 min average, as shown in Table 12.

A summary of the results obtained on Sections C, G, H and J is shown in Table 13. The total observed passes in each section is shown in Column 5, and all are reasonably similar in number. The observations extended over the period December to February in all sections, with a few in March, and should therefore be comparable. Column 4 of Table 13 shows the ratio of sanding to salting passes. It can be seen here that Section G has a lower ratio than the other sections and a somewhat higher mean clearing time. The patrol operating Section G follows the M-700-C Guidelines and uses salt for snow and ice removal, and sand for skidproofing. Hence, in Section G there were fewer sanding passes than salting passes and the average salt per pass was 85 kg/km in Section G_1, which represented their usual operation. The salt per pass in Section G_2 was higher due to the 15% salt content in the sand which was used in the same manner as the sand in Section G_1. These sections were declared clear in an average of 96 min after the final pass.

In Sections C, H, and J, there seemed to be a desire to clear the road much faster, yet the traffic was only about 1000 vehicles per day heavier. In these sections, the ratio of sand to salt passes (shown in Column 4) was higher, showing a tendency to use the sand-salt mixture to de-ice the road rather than relying on the salt alone. The greater

number of sand passes in Sections H and J_1 when compared to C and J_2, illustrates this point. Even though the sand in H and J_1 had only 5% salt, it was used as if it had 15% and, as a result, more had to be used.

4/ GENERAL DISCUSSION

This investigation has shown that the guidelines in M-700-C are reasonable for present level of service. The present level of service is not, however, fully defined as each District and Patrol have their own interpretation and clear the road as fast as they see fit to stay out of trouble.

The recommended salting rate of 130 kg/km is a good average figure, but for maximum efficiency and saving of salt, it should be varied depending on weather conditions. An attempt was made to develop an equation which would predict the amount of salt required for a given set of conditions. This equation will require some modifications to take into account the traffic and the amount of solar radiation falling on the road. With these modifications, it would help to conserve salt by preventing over-salting or under-salting and thereby requiring an extra salting pass. As the situation now stands, the patrolmen tend to modify the recommended amount of salt (130 kg/km) to be used as their own personal experience dictates. The attempt made in this investigation to obtain a regression equation to equate clearing time to weather conditions was a failure because the patrolmen interpreted the conditions differently, and some were prone to use mixtures rather than straight salt.

The guidelines in M-700-C are not being followed in the majority of areas studied. Winter maintenance practices vary within each Region, within Districts and even, at times, within a Patrol. This is illustrated here within Eastern and Central Regions. In only one of the eight sections studied could one say that the guidelines were being reasonably followed. In Sections A and D, much emphasis was placed on straight salt with very little use of sand. In Sections B, E, and F, great emphasis was placed on mixtures, mainly at the 50% salt level, with very little use of straight salt. Section G alone seemed to be operating close to the guidelines. Sections C, H, and J used a lot of 100% straight salt but preferred to use 15% salted sand rather than the recommended 5% salted sand.

The concept of the urgency to clear the road also varied. This is shown

in Column 7 of Table 12. The average final clearing times varied all the way from 36 min to 167 min. The slowest clearing times were in the sections where mixtures were in general use. This suggests a lack of direction on what is actually required -- how fast a road should be cleared during and after a storm.

Present practice seems to be to plow and salt (or sand) during a storm and continue until the storm stops. Each patrol is supplied with a sufficient number of plows and personnel, so that never more than a given amount of snow will accumulate on the road. Considerable salt would be saved if a policy were enforced that salt would only be used at the beginning of a storm to prevent the snow from sticking and, at the end of the storm, to clear off the road. During the storm, plowing would be kept up to keep the snow down to the allowable maximum depth. Such a policy would require public awareness and the co-operation of the police. No doubt, at present, there is some pressure from the police regarding clearing and skidproofing the road during a storm, but their co-operation could be obtained if a firm policy were formulated. These same police do not hesitate to close a road if there is heavy blowing snow and the visibility is poor. It is interesting to note the number of salt and sand (mixture) applications during various storms. These can be seen in Tables 6 to 11. Opposite each date is shown the number of salting or sanding passes. These vary from 1 to 11 passes. The average number of passes per storm is 4. If these could be reduced, it is easy to see how much salt would be saved, and the amount entering the environment would be reduced if the above policy could be initiated.

The use of prewetted salt was a failure; it resulted in a dangerous, icy condition which required extra salt to remove the ice. This resulted from the Ministry's practice of windrowing the salt down the centreline of the road. There have been reports of successful use of prewetted salt in Germany. There, however, the prewetted salt was spun across the road, rather than being windrowed down the centreline. This type of spinning technique usually requires more salt than the windrowing technique to accomplish the same road clearance. It is, therefore, dubious if any salt would be saved by spinning prewetted salt across the road over our current practice of windrowing the dry salt.

The use of paved shoulders to reduce the amount of salt spray blowing into neighboring fields is of some value. The reduction is small, but it could be good from a public relations point of view. The use of snow fencing on the security or farm fence to prevent salt spray from entering orchards was of extremely marginal or no use, and should not be considered for future applications.

The use of Verglimit to prevent pavement icing has been covered in a previous internal report. This material helps prevent pavement icing on bridge decks and hazardous road sections, but would be of little effect in conserving salt usage; it is chiefly useful as a material to make the road safer.

The pros and cons of using mixtures are more difficult to define. The use of sand appears to be somewhat governed by external circumstances. Sand is rather scarce and more expensive where Sections A and D are situated, hence, a heavier use of salt. Sand is plentiful where Sections B, E, and F are situated, hence its greater use there, but some other circumstances must also have been active to influence such heavy use of mixtures. The use of 15% salted sand in the Districts where Sections C, H, and J are situated has been preferred over the years for reasons either real or fancied, but without any actual experimental evidence. The results of this investigation have shown that roads can be kept clear and in quite reasonable time using straight salt and 5% salted sand, as was done in Sections A, D, G_1, H, and J_1.

The use of mixtures in Sections B, E, and F compared to salt and 5% salted sand in Sections, A, D, and G, leads to the following conclusions, as illustrated in Table 12.

In Sections A and B, more total salt was used and there were more treatments in A than in B (Columns 4 and 5), but there were 3400 more vehicles per day in B than in A to help clearance. Yet, the clearing time in A was more than three times faster than in B. If less salt had been used in A, and a longer clearing time allowed, considerably less salt and fewer trips would have been necessary.

In Sections D and E, the traffic and total salt used were essentially the

same but the effort expended in D was less, there were 21% fewer salting trips in D than in E. The clearing time was also less in D than in E. This indicates greater efficiency for the use of salt over mixtures.

Again, in Sections F and G, there is trouble in making a comparison. The traffic in Section G was almost 2000 vehicles per day heavier than in Section F, and there were about 15% more salting passes in G than in F. Yet, over 50% less total salt was used to maintain Section G than in Section F and, again, the clearing time was less in G than in F.

The conclusion to be drawn from comparing these three pairs of sections would have to be in favour of salt applications over mixture applications. Where mixtures are used, more effort has to be expended -- one 5 t truckload of salt spread at 130 kg/km will cover an area equal to 2.7 trucks of mixture spread at 340 kg/km, or 4.4 trucks of mixture spread at 560 kg/km.

The comparisons of the effect of 5% or 15% salt in the sand was not as easy. In the sections in which these two materials were compared (Sections C and H, Sections G_1 and G_2, and Sections J_1 and J_2), the road was cleared and kept open to traffic with very few problems in both the 5% and 15% sections. In the G sections, the sand was used only for skidproofing and no advantage was found for the 15% material. Table 12 shows more salt per kilometre was used in the 15% section than in the 5% section. In the C and H sections comparison, there is some doubt because the 5% material ran short in Section H and had to be supplemented with 15% material. The road, however, was kept open and less salt per kilometre was used than in Section C. In Sections J_1 and J_2, another effect can be seen. There, the patrol tried, at times, to de-ice Section J_1 with the 5% material and had to use 21% more passes than in Section J_2 -- yet, Section J_1, used still less salt per kilometre than Section J_2. In all cases in which the 5% material was used, there was less salt used per kilometre of road than in the sections in which the 15% material was used, and the road was kept open and suitable for traffic. The operation in Sections G_1 and G_2 shows that by working according to the guidelines, the road can be kept open and in good condition with 5% salted sand and applications of 100% salt, and use less salt per kilometre than with the use of mixtures or 15% salted sand.

There was one other section wherein 5% and 15% salted sand was tested. Unfortunately, the observer at this station did not report any 100% salting passes. When the omission was noted, it was too late to rectify the matter, and the results from this section had to be dropped.

5/ CONCLUSIONS

1/ The recommended salting rate of 130 kg/2-lane km is a good average rate; however, it requires modification for different weather conditions. This is now done by a rule of thumb, which varies from patrol to patrol.

2/ A salting rate prediction equation was developed. This could result in a saving of salt; however, the equation requires further testing and expansion to include more variables.

3/ The technique of plow only and do not use salt was tested and found to result in hazardous situations in a very short time under the present traffic levels.

4/ The use of prewetted salt was tested as a means of reducing salt usage. It was found that under this Ministry's type of road clearance operation, it results in pavement icing. This required a further application of salt and sand to remove the dangerous situation.

5/ Two different methods were tried as a means of preventing road spray from blowing into adjacent properties. Paved shoulders offered some small amount of reduction. The snow fencing installed on the security fence offered virtually no reduction.

6/ The use of an anti-icing compound incorporated into the asphalt surfacing of bridge decks was shown to reduce pavement icing. It is a good safety measure but would not make any significant reduction in overall salt usage.

7/ The use of sand-salt mixtures, 20% salt and higher, as de-icing mixtures works well, but mixtures are slower acting than straight salt and result in increased salt usage.

8/ The use of 15% salted sand, rather than 5%, was tested and did appear to increase the use of salt overall. This technique requires some

further testing under controlled conditions before a firm conclusion can be drawn.

6/ RECOMMENDATIONS

If the amount of salt used in Ontario is to be reduced, it can be accomplished by the following means:

1/ Strict adherence to the current guidelines, which are satisfactory. Use salt only for de-icing purposes and sand only for skidproofing a road when the temperature is not suitable for the use of salt.

2/ Use a prediction method to determine how much salt should be used under a given set of circumstances.

3/ Salt only after the beginning of a storm and to clean up after a storm is finished, rarely during the course of a storm. Never salt before the arrival of a storm.

4/ Reduce the level of service by giving the patrol more time to clear a road, by greater use of plowing, by less bare pavement on our two-lane roads with lower traffic volumes, and by greater volume of centre-bare pavement.

5/ A training course to bring all new and old Patrolmen and Supervisors into line with the recommended winter maintenance practices, and insistence on their application in all areas.

6/ Inform the public and obtain the co-operation of the police for the new level of service.

7/ A possible further study into the use of 15% mixtures. Contrast several pairs of sections where in one section of each pair 15% sand would be used both for skidproofing and for some de-icing, while in the other section, strict adherence to the guidelines would be followed and only 5% salt used for skidproofing.

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Table 1/ Salt Spray in Orchards
Winter 1977-78

Average Cl^- mg/m^2 per Standard Salting Pass

	Paved Shoulders		Gravel Shoulders		Average	
Section	A	D	B	C	Paved	Gravel
Distance From Hwy (Metres)						
18	77.8	64.8	144.2	48.6	71.3	96.4
24	45.4	45.4	118.3	29.2	45.4	73.8
30	30.8	45.4	81.1	30.8	38.1	56.0
					Mean Average	
Totals	154.0	155.6	343.6	108.6	51.6	75.4

Table 2/ Salt Spray in Orchards
Winter 1978-79

Average Cl^- mg/m^2 per Standard Salting Pass

	Paved Shoulders			Gravel Shoulders					Average	
									Paved	Gravel
Section	A	D	H	B	C	E	F	G	A,D, H	B,C,E F,G
Distance From Hwy (Metres)										
18	61.7	47.1	53.6	47.1	68.2	89.3	47.1	95.8	54.1	69.5
24	48.7	39.0	39.0	35.7	47.1	82.8	35.7	60.1	42.2	52.3
30	45.5	27.6	30.8	32.5	40.6	39.0	30.8	29.2	34.6	34.4
									Mean Average	
Totals	155.9	113.7	123.4	115.3	155.9	211.1	113.7	185.1	43.6	52.1

Table 3/ Salt Spray Penetration into Orchard, 1979

% Wt. Cl^- in Moss Bags
Two Exposure Periods: 1/ Jan. 23 to Feb. 21; 2/ Feb. 21 to March 23

Moss Bag Distance, m From QEW	Tree Row No.	Cl^- % Wt. of Moss	
		Exposure 1	Exposure 2
38*	2	3.1	0.46
38	2	0.9	0.32
50	4	1.25	0.20
74	8	0.25	0.12
122	16	0.34	0.04
218	32	0.16	0.03
410	64	0.10	-

* Values in this row from moss bags exposed on metal support, 2 m height, 50 m west of other bags.

TABLE 4/ MULTIPLE REGRESSION DATA FOR MULTI-LANE ROADS

SECTION	N CORRECTED TOTAL	F Value	PR. > F	R - SQUARE	C.V.	STD. DEV.	Y MEAN ROAD CLEAR, MIN	ESTIMATES (COEFFICIENTS)								
								INTERCEPT	X_1 SKY	X_2 ROAD SURFACE	X_3 SUN SHINING	X_4 WEATHER COND.	X_5 DEPTH OF SNOW	X_6 % SALT	X_7 SPREADING RATE	X_8 TEMP.
A	36	2.58	.034	.384	41.1	32.1	78.0	263.5B	-8.9	-25.4	-50.5	-8.7	3.6	B	-0.03	1.0
B	35	1.08	.406	.242	43.0	100.	232.5	-260.3	7.7	115.5	150.9	-13.4	-2.7	31.7	0.1	-6.5
C	26	17.04	.0001	.863	29.6	10.7	36.2	330B	-11.5	8.9	-130.7	-1.35	2.37	-0.6B	B	-0.97
ALL SECTIONS	80	1.18	.321	.116	75.3	107.4	142.6	37.2	3.6	41.2	43.7	4.1	8.4	-11.1	-0.1	-0.7

TABLE 5/ MULTIPLE REGRESSION DATA FOR TWO-LANE ROADS

SECTION	N CORRECTED TOTAL	F Value	PR. > F	R - SQUARE	C.V.	STD. DEV.	Y MEAN ROAD CLEAR, MIN	ESTIMATES (COEFFICIENTS)								
								INTERCEPT	X_1 SKY	X_2 ROAD SURFACE	X_3 SUN SHINING	X_4 WEATHER COND.	X_5 DEPTH OF SNOW	X_6 % SALT	X_7 SPREADING RATE	X_8 TEMP.
D	25	5.46	.002	.680	52.1	42.3	81.2	-157.48	1.8	19.7	42.3	19.9	-10.4	B	0.7	-1.0
E	26	0.99	.475	.306	71.3	73.3	102.8	160.8	-14.4	53.7	-42.9	-8.3	6.7	-11.0	0.3	-1.8
F	47	5.40	.001	.526	54.2	62.8	115.9	336.8	-29.2	63.4	-48.2	10.6	-12.3	9.6	-0.01	-6.2
G	39	0.61	.766	.135	64.6	62.0	96.0	88.8	0.2	-10.7	-59.3	2.6	-6.7	9.1	0.2	1.9
H	10	0.66	.724	.715	62.2	46.3	74.6	-22596.	12.0	16.8	41.5	-18.1	-55.3	3212.	27.7	-1.5
J	17	7.77	.003	.874	32.7	14.5	44.2	102.1	-10.3	2.0	-19.0	3.4	16.7	-1.8	0.01	-1.4
ALL SECTIONS	169	2.73	.008	.120	71.2	66.6	93.6	-14.7	-9.4	13.6	-6.9	8.1	-5.1	15.0	0.2	-0.9

Table 6/ Comparison of De-icing Operations -- Sections A & B
Multi-lane Highway

Date	Section A		Section B	
	No. of * Treatments	Sum** (kg/km)	No. of ** Treatments	Sum** (kg/km)
Nov. 21	1d	135	1d	119
22	1d	135	1d	119
27	2d	270	1a	88
Dec. 8	2d	350	1b, 1d	224
9	1d	126	1d	119
23	3d	464	3d	381
28	7d	1,183	1b, 4d	641
Jan. 4	5d	774	2b, 2d	492
5	1d	126	3d	430
8	1d	169	2b, 1d	380
28	1d	169	3b	350
29	1d	169	1b	120
30	2d	353	2d	366
Feb. 1	5d	789	1c	120
4	11d	1,805	5b, 5d	1,888
9	4d	590	5b, 2c	748
19	5d	845	1c, 1d	331
Mar. 1	3d	421	1b, 3c	675
4	11d	1,475	6d	990
9	4d	547	3b	396
Totals	71	10,895	63	8,977

*Treatments -
a = Sand with 33% Salt
b = Sand with 50% Salt
c = Sand with 70% Salt
d = 100% Salt

**Sum = Total Salt Appplied in kg/km

Table 7/ Comparison of De-icing Operations -- Sections D & E Two-Lane Highway

Date	Section D		Section E	
	No. of * Treatments	Sum** (kg/km)	No. of * Treatments	Sum** (kg/km)
Nov. 26	2e	250	1d	175
28	1e	125	1c	115
Dec. 7	1e	125	1b, 1d	165
22	1e	135	2d	311
23	1e	200	1d	155
28	4 }e		3d, 1e	527
29		910	2d	267
Jan. 1	2e	260	1d, 1e	337
4	3e	390	1a, 1d, 4e	720
28	2e	290	} 1a, 1b, 4d	
29	1e	145		622
30	4e	869	1d	134
31	1e	145	} 2d	
Feb. 1	2e	290		302
3	2e	290	} 5d, 1e	
4	2e	335		920
6	4e	580	4d	422
7	0	0	2d	125
9	1e	145	1d	125
23	2e	290	1d	133
Mar. 1	2e	290	2d	277
4	4e }		2d	259
6		620	4d	604
7	1e	145	1d	127
9	1e	145	1d	140
17	3e	580	3d	322
Totals	47	7,554	57	7,284

*Treatments -

a = Sand with 5% Salt
b = Sand with 15% Salt
c = Sand with 33% Salt
d = Sand with 50% Salt
e = 100% Salt

**Sum = Total Salt Used, kg/km

Table 8/ Comparison of De-icing Operations -- Sections F & G
Two-Lane Highway

Date	Sections F_1 and F_2 Combined		Sections G_1 and G_2 Combined	
	No. of * Treatments	Sum** (kg/km)	No. of * Treatments	Sum** (kg/km)
Dec. 7	8d	1,293	1a, 1b, 4e	513
21	2d	416	2a, 3e	228
22	4d	530	1a, 1b, 2e	373
23	7d, 1e	1,225	1a, 1b, 4e	573
27	3d	558	2a, 2b, 4e	748
29	1b, 1c, 5d	1,191	2a, 2b, 4e	748
Jan. 1	6d	1,184	1a, 1b, 4e	632
4	2c, 6d, 2e	1,649	2a, 2b, 4e	748
6	2d	394	1b	85
24	7d	1,163	2a, 2b, 4e	748
Feb. 1	2a, 2d	435	2a, 2b, 4e	618
4	2c, 5d	1,186	2b, 8e	1,210
19	5d	998	2a, 2b, 4e	748
Mar. 9	3d	602	2a, 2b	228
16	4c	526	2b, 2e	560
Totals	80	13,350	94	8,760

*Treatments -
a = Sand with 5% Salt
b = Sand with 15% Salt
c = Sand with 33% Salt
d = Sand with 50% Salt
e = 100% Salt

**Sum = Total Salt, kg/km

Table 9/ Comparison of De-icing Operations -- Sections G_1 & G_2 Two-Lane Highway

Date	Section G_1		Section G_2	
	No. of * Treatments	Sum** (kg/km)	No. of * Treatments	Sum** (kg/km)
Dec. 7	1a, 2c	228	1b, 2c	285
21	2a	57	3c	171
22	1a, 1c	158	1b, 1c	215
23	1a, 2c	228	1b, 2c	345
27	2a, 2c	317	2b, 2c	431
29	2a, 2c	317	2b, 2c	431
Jan. 1	1a, 2c	288	1b, 2c	344
4	2a, 2c	317	2b, 2c	431
6	-	-	1b	85
24	2a, 2c	317	2b, 2c	431
Feb. 1	1a, 1b, 2c	374	1a, 1b, 2c	244
4	1b, 4c	605	1b, 4c	605
19	2a, 2c	317	2b, 2c	431
Mar. 9	2a	57	2b	171
16	1b, 1c	345	1b, 1c	215
Totals	46	3,925	48	4,835

*Treatments -
a = Sand with 5% Salt
b = Sand with 15% Salt
c = 100% Salt

**Sum = Total Salt, kg/km

Table 10/ Comparison of De-icing Operations -- Sections C & H
Four-Lane Highway, Section C -- Two-Lane Highway,
Section H

Date	Section C		Section H	
	No. of * Treatments	Sum** (kg/km)	No. of * Treatments	Sum** (kg/km)
Dec. 8	1b	94	1a, 1c	156
17	1b, 2c	344	3a, 1c	194
21	2b, 1c	312	1a, 1c	156
22	1b, 1c	219	1a, 1c	156
27	1c	125	2a, 1c	187
Jan. 3	1b	219	1a, 1c	156
7	1b, 1c	219	1a, 1c	156
13-14	5b, 2c	719	4a, 3c	499
16	2b	186	1a	31
21	1b	93	1a	31
23	1b, 2c	343	2a, 2c	312
30	1b, 2c	343	1a, 2c	281
Feb. 4	1b, 1c	219	1b, 1c	219
5-6	2b, 1c	311	3b	281
13-14	2b, 1c	311	2b, 1c	311
4-5	3b, 3c	654	4b, 2c	622
7	1b	93	1b	93
25	1c	125	1c	125
Totals	45	4,929	49	3,966

*Treatments -
a = Sand with 5% Salt
b = Sand with 15% Salt
c = 100% Salt

**Sum = Total Salt Used, kg/km

Table 11/ Comparison of De-icing Operations -- Sections J_1 & J_2 Two-Lane Highway

Date	Section J_1		Section J_2	
	No. of * Treatments	Sum** (kg/km)	No. of * Treatments	Sum** (kg/km)
Dec. 8	2a, 3b, 3c	762	-	-
10	3a	106	5b, 2c	672
17	3a, 2c	355	2b, 4c	669
21	3a, 4c	605	3b, 2c	503
Jan. 13-14	5a, 3c	551	3b, 3c	628
16	3a, 1c	230	3b, 1c	378
30	1a, 1c	160	2b, 1c	294
Feb. 3-4	1a, 2b, 3c	621	4c	604
5-6	2a, 1b	175	3b, 2c	564
Mar. 3-4	3a, 3c	490	2b, 1c	355
Totals	52	4,055	43	4,667

*Treatments -
a = Sand with 5% Salt
b = Sand with 15% Salt
c = 100% Salt

**Sum = Total Salt Used, kg/km

Table 12/ Summary of De-Icing Operations

Section	De-icants % Salt	Traffic WADT*	Observed No. of Treatments	Observed Total Salt (kg/km)	Average Salt per Treatment (kg/km)	Mean Clearing Time (Min)
A	100	7,880	71	10,895	153	53
B	Mixt. & 100	11,343	63	8,977	142	167
D	100	2,880	47	7,554	161	81
E	Mixt.	2,888	57	7,284	128	103
F_1	Mixt.	2,450	41	6,589	161	116
F_2	Mixt.	2,450	39	6,961	178	116
G_1	5 & 100	3,817	46	3,925	85	96
G_2	15 & 100	4,867	48	4,835	101	96
C	15 & 100	10,467	45	4,929	110	47
H	5 & 100	4,950	49	3,966	81	36
J_1	5 & 100	4,258	52	4,055	78	74
J_2	15 & 100	5,419	43	4,667	109	74

*WADT = Winter Average Daily Traffic.

Table 13/ Comparison of 5% and 15% Salted Sand Operations

Section and % Salt in Sand	Sanding Passes	Salting Passes	Ratio Col.2/Col.3	Total Passes	Averge Salt per Pass (kg/km)	Mean Clearing Time (Min)
G_1, 5	22	24	0.9	46	85	96
G_2, 15	21	27	0.8	48	101	96
C, 15	26	19	1.4	45	110	47
H, 5	30	19	1.6	49	81	36
J_1, 5	32	20	1.6	52	78	74
J_2, 15	23	20	1.2	43	109	74

Table 14/ Final Summary of 1981-82 Observed Winter De-icing Operations

Section	No. of 100% Salt Applications	No. of 5% and 15% Salt in Sand Applications	No. of 33, 50, & 70% Salt in Sand Applications	Total No. of Treatments	Average Salt Applied per Treatment (kg/km)
A	94	-	-	94	151
B	47	2	58	107	138
D	70	-	-	70	162
E	7	10	51	68	135
F	3	8	107	118	172
G	61	68	1	130	95
C	31	37	-	68	108
H	26	44	-	70	79
J	41	55	-	96	92

Figure 1/

100 kg/Salt/km Section. Melting stopped, packed snow and ice forming.

Figure 2/

130 kg Salt/km Section. Road bare and slushy in spots.

Figure 3/

155 kg Salt/km Section. Road partly wet. No salt residue.

Figure 4/

185 Salt/km Section. Road bare and dry. Salt residue down centreline.

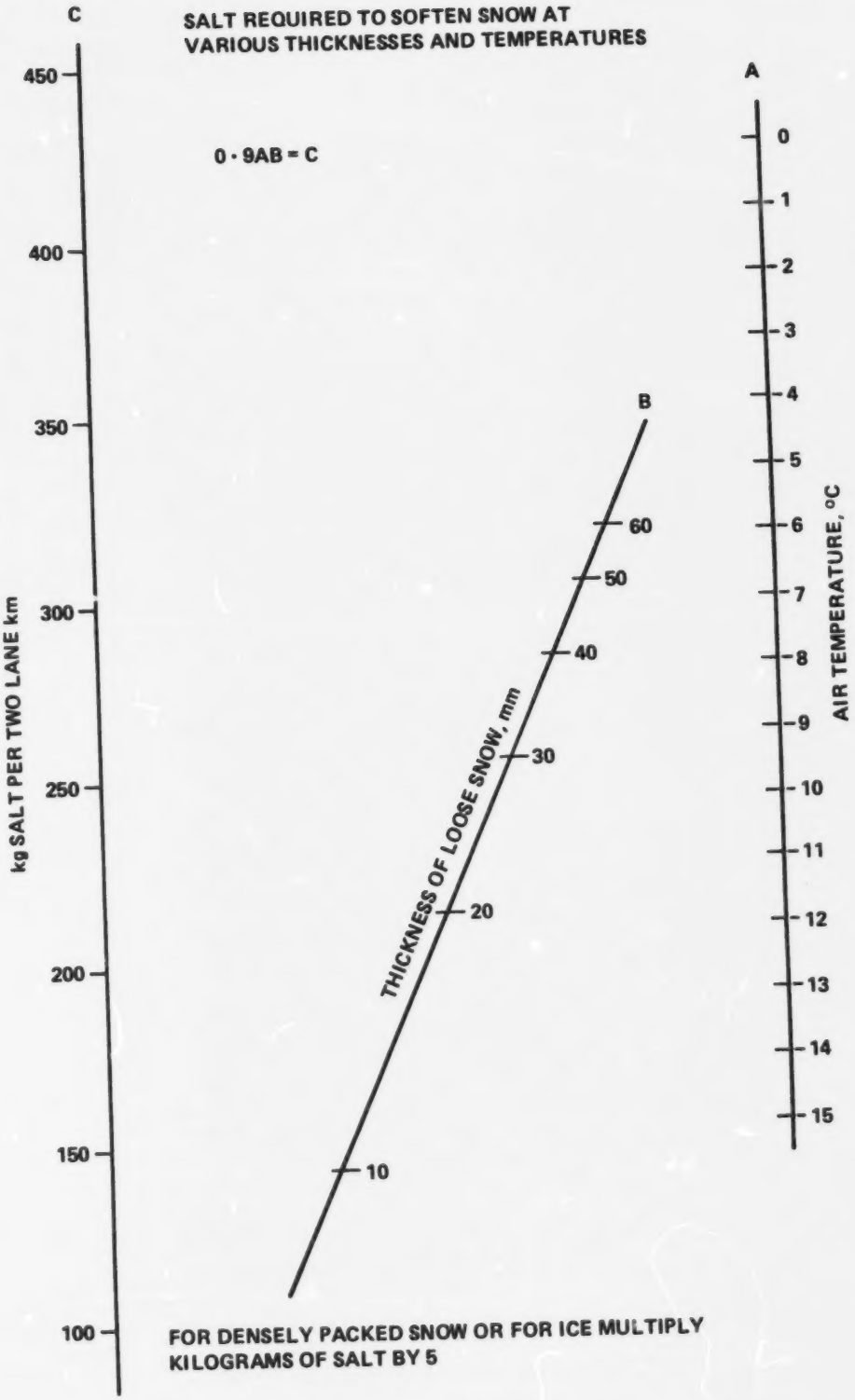

Figure 5/ Nomograph to Determine Salt Required from Depth of Snow & Air-Temperature

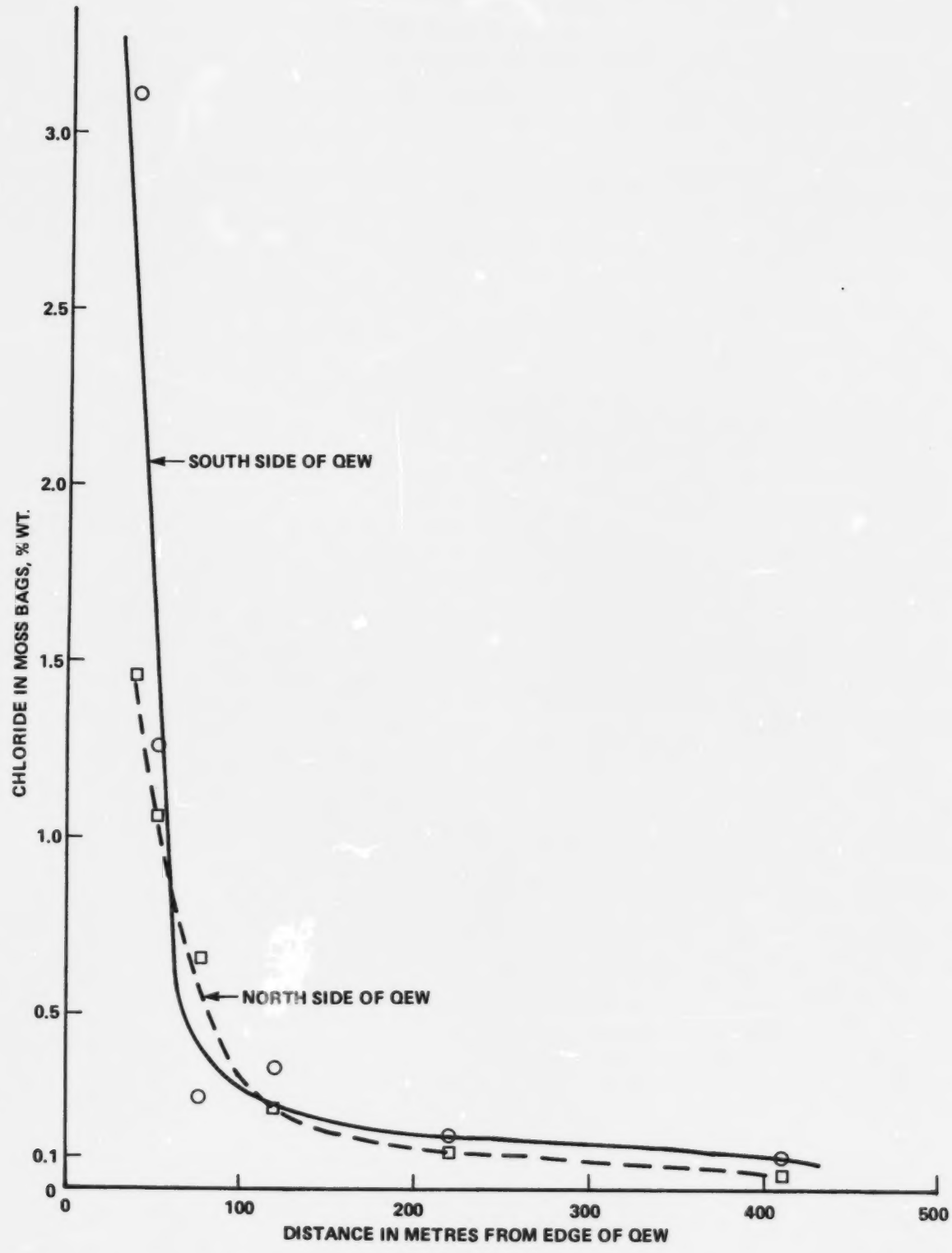

Figure 6/ Salt Spray in Orchard, Chloride Levels vs Distance
(30 Days, Jan. 23-Feb. 21, 1979)

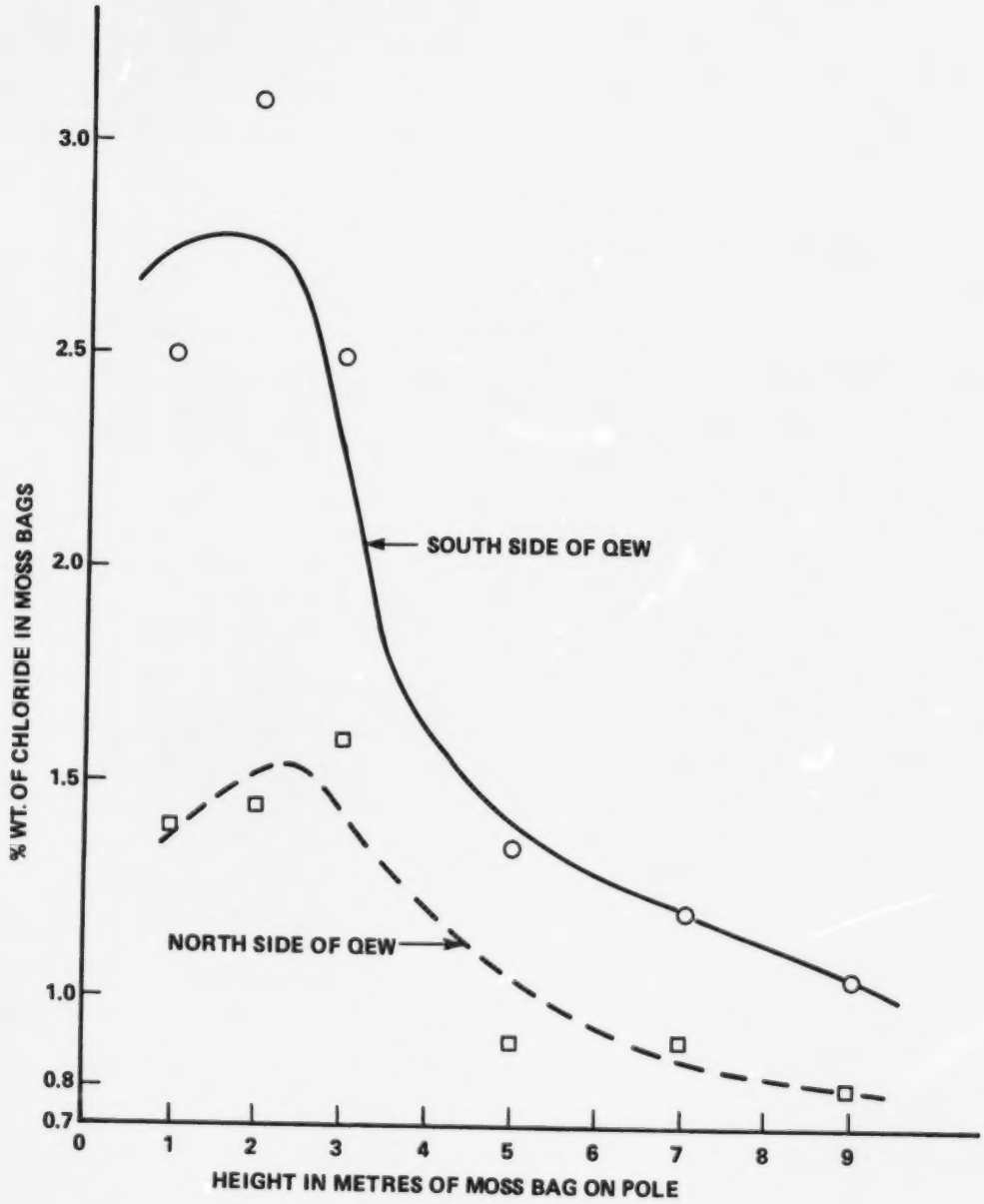

Figure 7/ Chloride Levels vs Height (30 Days Exposure, Jan. 23-Feb. 21, 1979) - Poles 38 m from QEW

WINTER MAINTENANCE STUDY
PROJECT 22507, 1981 - 82

1 CARD No. - Col. ☐☐☐☐☐
1 2 3 4 5

2 CONTINUATION FROM CARD No. - Col. ☐☐☐☐☐
6 7 8 9 10

3 DATE - Col. ☐☐☐☐☐☐
11 12 13 14 15 16

4 ROAD SECTION - Col. 17 A B C D E F G H J K
☐☐☐☐☐☐☐☐☐☐
0 1 2 3 4 5 6 7 8 9

Figure 8a/ Observers Record Form

| | | |

13	Time Storm Began Col. ☐ 28 ☐ 29 • ☐ 30 ☐ 31
14	Pavement Condition Dry Snow ☐ 1 Snow sticking to Pavement ☐ 2 Icing under Traffic ☐ 3 Col. 32
15	First Action Plow First ☐ 1 Sanding Behind Plow ☐ 2 Sand (Salt) First ☐ 3 Col. 33
16	Time of First Action Col. ☐ 34 ☐ 35 • ☐ 36 ☐ 37
17	Treatment, % Salt 5% ☐ 1 15% ☐ 2 20%(4:1) ☐ 3 33%(2:1) ☐ 4 50%(1:1) ☐ 5 100% ☐ 6 Other ☐ 7 Col. 38
18	Spreading Rate, kg/km Col. ☐ 39 ☐ 40 ☐ 41 ☐ 42
19	Application Time Col. ☐ 43 ☐ 44 • ☐ 45 ☐ 46
20	Effect of Treatment - 2 Lane Road Time to Achieve: Center Bare, ☐ 47 • ☐ 48 ☐ 49 Col. Track Bare, ☐ 50 • ☐ 51 ☐ 52 Col. Road Clear, ☐ 53 • ☐ 54 ☐ 55 Col. Treatment Satisfactory Yes ☐ 1 No ☐ 2 Col. 56

Figure 8c/ Observers Record Form

21 Effect of Treatment - Multi-lane 401
Time to Achieve:

Col. Track Bare, Driving Lane ☐ ☐ ☐ (57 58 59)

Col. Driving Lane Bare ☐ ☐ ☐ (60 61 62)

Col. Passing Lane Bare ☐ ☐ ☐ (63 64 65)

Col. Third Lane (if present) Bare ☐ ☐ ☐ (66 67 68)

Treatment Satisfactory Yes ☐ (1) No ☐ (2)

Col. 69

22 Condition Continues, Road not Clear
Continued on Card No.

Col. ☐ ☐ ☐ ☐ ☐ (70 71 72 73 74)

Figure 8d/ Observers Record Form